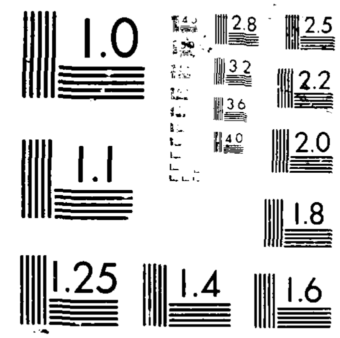
AD-A193 008 ON THE CONJUGACY OF THE AURORA: HIGH AND LOW LATITUDES 1/1
(U) AEROSPACE CORP EL SEGUNDO CA SPACE SCIENCES LAB
P F MIZERA ET AL. 05 FEB 88 TR-0086A(2940-06)-4
UNCLASSIFIED SD-TR-88-09 F04701-85-C-0086 F/G 4/1 NL


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

REPORT SD-TR-88-09

AD-A193 008

On the Conjugacy of the Aurora: High and Low ~~Altitudes~~ Latitudes

P. F. MIZERA and D. J. GORNEY
Space Sciences Laboratory
The Aerospace Corporation
El Segundo, CA 90245

and

D. S. EVANS
Space Environment Laboratory
NOAA
Boulder, CO 80303

5 February 1988

Prepared for

SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Base
P.O. Box 92960, Worldway Postal Center
Los Angeles, CA 90009-2960

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-85-C-0086 with the Space Division, P.O. Box 92960, Worldway Postal Center, Los Angeles, CA 90009. It was reviewed and approved for The Aerospace Corporation by H. R. Rugge, Director, Space Sciences Laboratory. Lt Clarence V. Wilcox/CLTPC was the project officer for the Mission-oriented Investigation and Experimentation (MOIE) Program.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Clarence V Wilcox

CLARENCE V. WILCOX, Lt, USAF
MOIE Project Officer
SD/CLTPC

Raymond M Leong

RAYMOND M. LEONG, Major, USAF
Deputy Director, AFSTC West Coast Office
AFSTC/WCO OL-AB

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) TR-0086A(2940-06)-4	5. MONITORING ORGANIZATION REPORT NUMBER(S) SD-TR-88-09
6a. NAME OF PERFORMING ORGANIZATION The Aerospace Corporation Laboratory Operations 6b OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Space Division
6c. ADDRESS (City, State, and ZIP Code) El Segundo, CA 90245	7b ADDRESS (City, State, and ZIP Code) Los Angeles Air Force Base Los Angeles, CA 90009-2960
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F04701-85-C-0086-P00016
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
On the Conjugacy of the Aurora: High and Low Latitudes

12 PERSONAL AUTHOR(S)
Mizera, P. F., Gorney, D. J., and Evans, D. S.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
	FROM ______ TO ______	1988, February 5	15

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Plasma measurements, Polar orbiting satellites, Auroral conjugacy, Electron precipitation

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

On December 5, 1983 the polar orbiting satellites NOAA-7 and DMSP-F6, while in opposite hemispheres, each crossed a narrow structure of auroral electron precipitation at nearly the same Universal Time (UT) and at the same high magnetic-latitude, local time location. The Operational Line Scanner (OLS) image taken by DMSP-F6 of the northern polar region showed that this enhancement was associated with a sun-aligned arc (SAA) which extended poleward from the midnight sector auroral zone and passed across the polar cap very near to the magnetic pole. The DMSP-F6 plasma measurements showed particle precipitation at background levels in the regions adjacent to the SAA suggesting that those magnetic field lines connected to the interplanetary medium via the northern tail lobe. NOAA-7 observations show that the analogous precipitation structure in the southern hemisphere was embedded in a region of low intensity ion and electron precipitation which had the characteristics of the plasma sheet population. Comparisons between the boundaries of the lower latitude auroral zone precipitation

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code) / 22c OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

19. ABSTRACT (Continued)

and the electron distributions at those boundaries were also made. The results of these comparisons together with those made for the high latitude SAA argue for a high degree of inter-hemisphere conjugacy in the electron precipitation over a wide range of invariant magnetic latitudes.

PREFACE

This work was supported in part by the USAF Systems Command's Space Division under Contract F04701-85-C-0086 and the National Environment Satellite, Data, and Information Service for support of the Space Environment Monitors.

CONTENTS

FIGURES

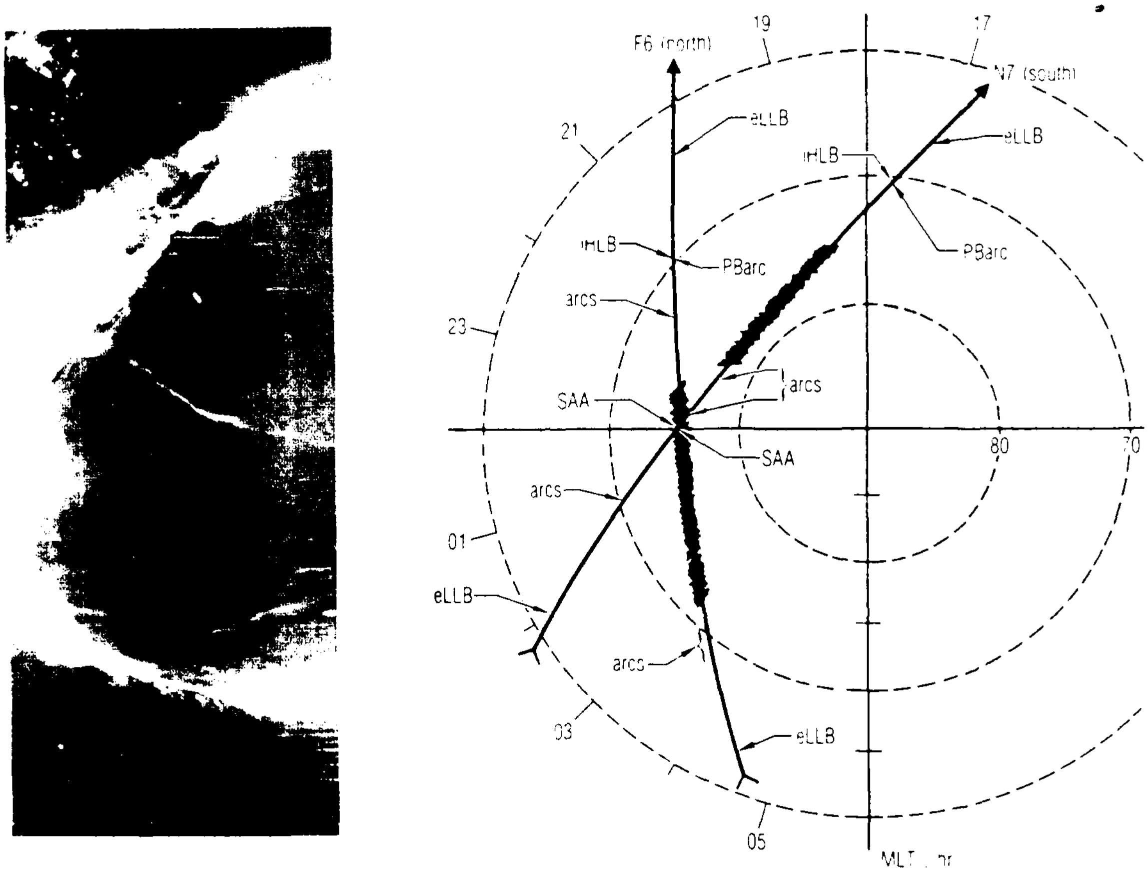
I. INTRODUCTION AND BACKGROUND

Past measurements using limited geographical fields-of-view from ground-based or aircraft instrumentation have shown a remarkable degree of auroral conjugacy [Akasofu, 1977 and references therein]. With the advent of plasma monitors on the NOAA and DMSP weather satellites, in situ measurements of global boundaries of the aurora in opposite hemispheres have become productive [Gorney et al., 1986; Mizera and Evans, 1986]. When the circumstances permit a visible image of the polar cap region to extend the in situ plasma measurements from the DMSP satellite, one is indeed fortunate.

Such an occurrence on December 5, 1983 was monitored by the DMSP-F6 (F6) and the NOAA-7 (N7) polar orbiting satellites as they traversed the north and south polar regions, respectively, near 20 hours UT. The OLS sensor on F6 produced the visible wavelength image of the entire night-side auroral zone from the dawn to dusk meridians that is shown in Fig. 1a. A prominent feature in this image is the sun-aligned arc (SAA) that is seen to extend poleward from the midnight sector of the auroral zone across the polar cap toward the sun. This arc passes within 5 degrees of the invariant magnetic pole.

Magnetic activity on December 5 was sporadic. The hourly AE index at the time of the satellites passes was 567 gammas while the 1 minute AE index showed a monotonic increase from 200 gammas one hour before to 750 gammas one hour after the satellite passes. The AL index did not reflect enhanced magnetospheric convection. The 1 hour averages of the field components showed that Bz was predominately negative for the first half of the day, although the magnitude of this component was less than 3 gammas. Later in the day, Bz became very small and fluctuated about 0. By was positive and Bx negative throughout the day except for the 1 hour average from 19 to 20 UT, just prior to the satellite passes, when these directions were reversed. The IMF rotated from an away to a toward solar direction indicating a discontinuity that lasted approximately 1 hour. The field was undergoing large fluctuations.

The level of auroral activity was quite high as evidenced by both the AE index and an intense region of aurora seen in the Fig. 1a.



(a) (b)

Fig. 1. a) DMSP-F6 Photo of the North Pole Taken on December 5, 1983; Dawn and Dusk are at the Bottom and Top, respectively, and Midnight is on the Left. b) 100 km trajectories of the NOAA-7 and DMSP-F6 Satellites Ploted in Invariant Latitude (Λ^0) and Magnetic Local Time (MLT, hr) Coordinates.

II. DMSP-F6 AND NOAA-7 PARTICLE OBSERVATIONS

Figure 1b shows F6 and N7 trajectories, as projected along the geomagnetic field from the satellite to 100 km altitude, plotted in invariant latitude (Λ) and magnetic local time (MLT) coordinates. The geomagnetic field model used in the ephemeris calculations was the International Geomagnetic Reference Field (IGRF) 1985.0 (IAGA Div. I., Working Gp. I). Magnetic local time is calculated by tracing along a field line to the magnetic equator where the angle relative to the earth-sun direction is determined. The curved vertical lines represent the coverage of the image in Fig. 1a. The different symbols along these satellite tracks mark various particle precipitation features such as intense arcs and boundaries in the diffuse auroral precipitation.

The F6 and N7 instruments measure the particle intensities and integrated energy fluxes for both electrons and positive ions with a time resolution of 1 and 2 seconds, respectively. Figure 2 shows the plots of the electron energy flux profiles (every 2 seconds) (in ergs/cm^2/sec) on a common invariant latitude coordinate. Universal Time (UT) is increasing from left to right for both satellites although the UT of the measurements differed by about 10 minutes at a given latitude. Magnetic local time at selected points is listed for both satellites at the top.

The electron low-latitude boundary (eLLB) was defined as the point where the electron energy fluxes reached 1 erg/cm^2/sec. In the post-midnight sector in Fig. 2, N7 encountered the eLLB at an invariant latitude of 61.6° and MLT of 1.9 hours. F6 encountered the eLLB at a latitude of 62.8° and MLT of 4.5 hours. A statistical study (Hill et al., 1982) showed the variation in the location of the eLLB as a function of MLT. For the level of activity present on December 5, the eLLB at 4.5 hours on the average lies 1.3° poleward of the eLLB at 1.9 hours. This statistical result is in good agreement with the 1.2° actually observed.

Figure 2 also shows that each satellite encountered the center of the post-midnight auroral zone, where energy fluxes reached approximately 10

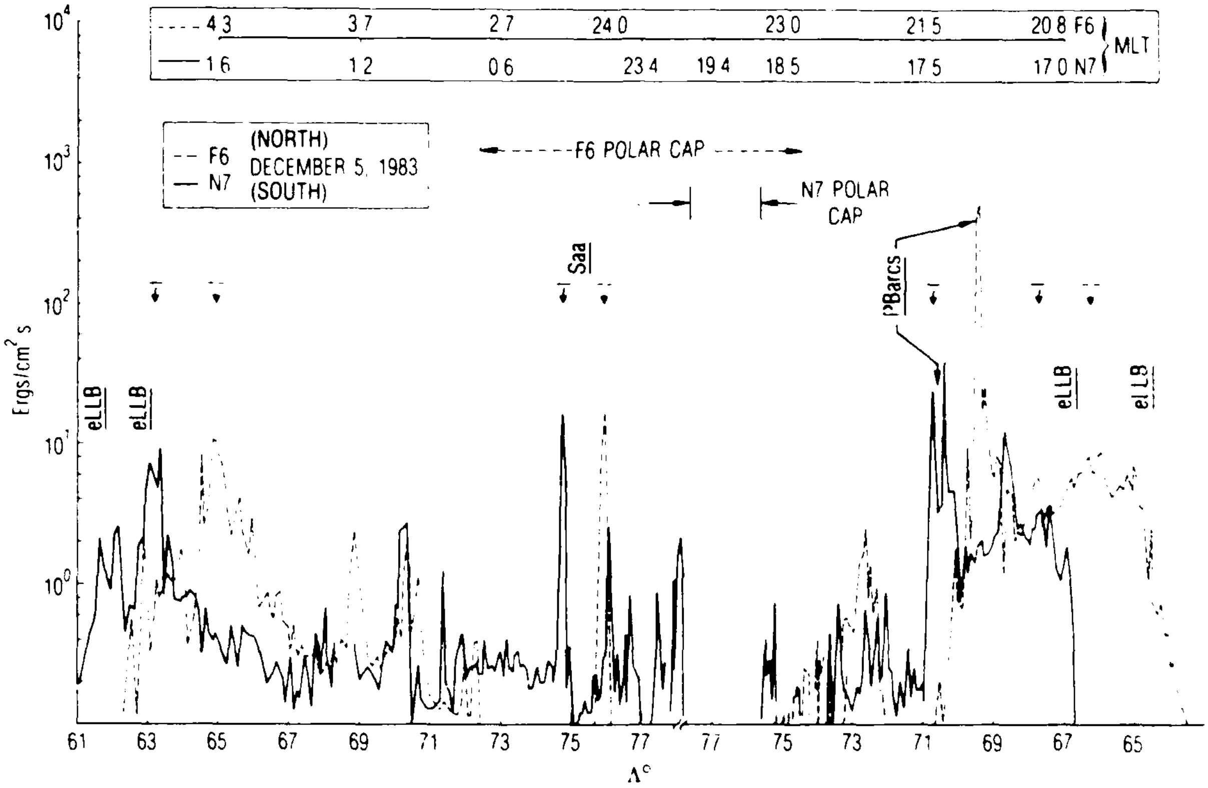


Fig. 2. Electron Energy Fluxes Plotted Along the Trajectories of N7 and F6 (See Fig. 1b). MLT is shown at the top as well as the regions indicated as the polar caps. The arrows denote where electron distributions are shown in Figures 3 and 4.

ergs/cm^2/sec, at locations a few degrees poleward of their respective eLLB. In the invariant latitude range of 69^o to 70^o, both N7 and F6 encountered structured electron precipitation reaching a few ergs/cm^2/sec associated with weak auroral arcs. The post-midnight auroral precipitation is very similar between the northern and southern hemispheres in terms of spatial structures and intensity of precipitation.

Both N7 and F6 encountered a single narrow structure of intense electron precipitation at high latitudes near local midnight. The F6 instrument measured precipitating electron energy fluxes of 17 ergs/cm^2/sec when the satellite passed over the sun-aligned arc (SAA) appearing in Fig. 1a at a location

near 76°. Some 12 minutes earlier, N7 observed a narrow enhancement in electron energy flux reaching about 16 ergs/cm^2/sec at a location of 74.7°.

These enhancements appeared at almost the identical magnetic location in opposite hemispheres. However, their locations, relative to what we identify as the polar cap, differed between the two hemispheres. The boundaries of the northern polar cap, as defined by the electron and ion energy fluxes being near background intensities of about .01 ergs/cm^2/sec (Makita et al., 1983), are brush marked in Fig. 1b and indicated in Fig. 2. The SAA observed by F6 in the north is in the polar cap with particle energy fluxes near background for many degrees of latitude on either side.

In contrast, the electron precipitation structure (SAA) observed by N7 lay embedded in a broad region of low intensity particle precipitation. This precipitation consisted of electrons of several 100 eV carrying 0.1 - 0.3 ergs/cm^{2}sec energy flux and positive ions of 2000 to 4000 eV energy carrying energy fluxes of between 0.03 and 0.1 ergs/cm^2/sec (integrated from 300 to 20000 eV). The significant contribution of positive ions to the low level precipitation suggests that these particles had their origin in a high latitude plasma sheet population.

N7 encountered a region where the precipitating energy fluxes fell to near background. This region, which we identify as the polar cap in the southern hemisphere, is displaced toward the dusk meridian compared to the northern hemisphere polar cap. This region is also brush marked in Fig. 1b and shown in Fig. 2.

Both F6 and N7 encountered intense energetic electron precipitation located at the poleward boundary (PB arc) of the dusk sector aurora. Both satellites also encountered an increase in ion precipitation from low levels to about 0.1 ergs/cm^2/sec (defining the ion high latitude boundary; iHLB) located near the intense electron precipitation. At this boundary the F6 satellite observed an electron surge distribution which peaked at energies greater than 30000 eV with energy fluxes exceeding 1200 ergs/cm^2/sec. N7, which encountered the poleward boundary about 3 hours earlier in MLT, observed that the average electron energy was about 6000 eV and the energy flux was

about 30 ergs/cm^2/sec. These differences are consistent with changes in the intensity of the aurora along the poleward edge of the dusk sector auroral oval at this time.

Finally, the electron low latitude boundaries (eLLB) in the evening local time sector, where the electron energy fluxes fell below 1 erg/cm^2/ sec, were crossed by N7 at a magnetic location of 66.8°, 17.0 hours MLT, and by F6 at 64.5°, 20.4 hours MLT. The Hill et al. (1982) study of the equatorward boundary location as a function of MLT indicates that, for a high level of activity, the equatorward boundary at 17.0 MLT would be located about 6° poleward of the equatorward latitude boundary at 20.4 MLT. We might not expect average statistical boundaries to apply to this dynamic situation.

Comparisons between electron energy spectrums taken at selected locations in the post-midnight and dusk sectors by F6 (in the north) and N7 (in the south), indicated by arrows in Fig. 2 are shown in Fig. 3. These locations were chosen to be in the centers of the electron precipitation zones in order to exclude the extremely intense electron precipitation observed by F6 at the poleward edge of the dusk oval. Figure 3 shows good agreement of the electron intensities and spectral shapes for the precipitation observed in the center of the post-midnight and evening auroral zones. This suggests that the precipitation in either hemisphere originates from a common plasma reservoir at these moderately high invariant latitudes.

Figure 4 shows a similar comparison between electron energy spectrums taken at the SAA precipitation enhancement observed in both hemispheres at invariant latitudes poleward of 74°. The two energy spectrums are virtually identical in spite of the very high magnetic latitudes of the observations. This excellent comparison shows that the particle sources and the electron acceleration processes are the same for the SAA observed nearly simultaneously at the same magnetic location in opposite hemispheres.

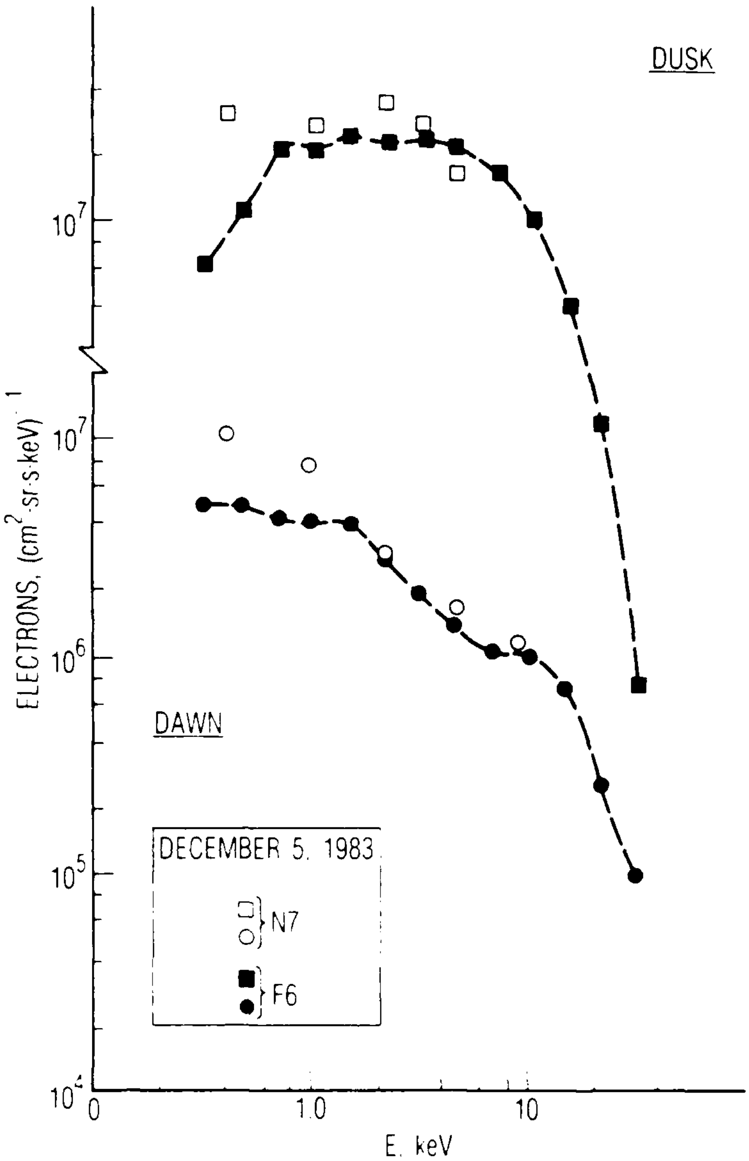


Fig. 3. N7 and F6 Electron Differential Flux Distributions for the Low Latitude Dusk (Top) and Dawn (Bottom) Auroral Regions (See Fig. 2).

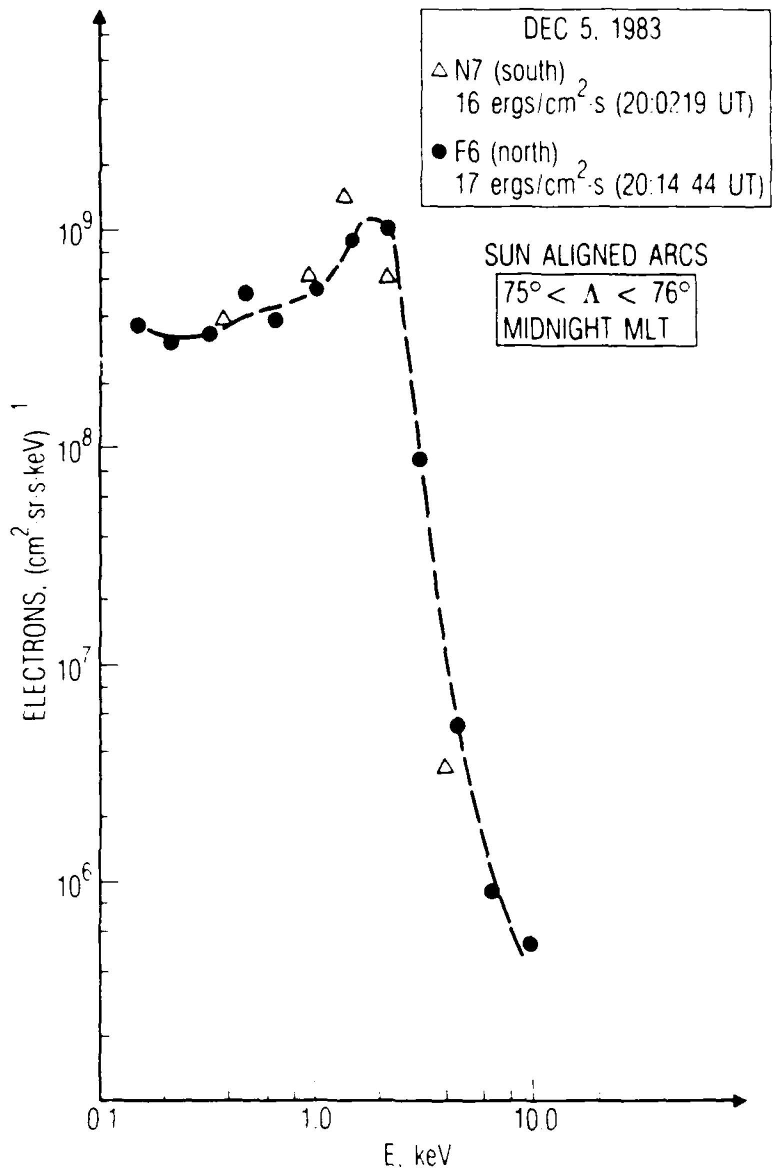


Fig. 4. N7 and F6 Electron Differential Flux Distributions for the Sun-Aligned Arc (SAA) Encountered at High Latitudes in Opposite Hemispheres. The error bars, associated with counting statistics, near the peak intensities are small compared with the symbols.

III. SUMMARY

The auroral precipitation patterns observed by particle detectors on board the DMSP-F6 satellite in the northern hemisphere and the NOAA-7 satellite in the southern hemisphere near 20 hours UT on December 5, 1983 have virtually the same morphologies. The electron energy fluxes (integrated between 300 eV and 20000 eV) displayed similar intensities and latitudinal behavior in opposite hemispheres over both the post-midnight and evening sectors of the auroral oval. Electron energy spectrums, taken near the centers of these sectors, were nearly the same. Inter-hemispheric differences in the location of the equatorward boundaries of the electron precipitation in the post-midnight sector were minor and could largely be accounted for by the normal variation in this boundary location with magnetic local time. A similar comparison in the dusk sector did not yield nearly such good agreement, undoubtedly because of large differences in the auroral morphology with magnetic local time.

The most striking observation made during these near-simultaneous passes over opposite polar regions was of a precipitation structure encountered by both satellites at nearly the same high-latitude location. This structure was shown to be associated with a sun-aligned arc (SAA) in the northern hemisphere and we infer from the data that N7 transited a near duplicate SAA in the southern hemisphere. Comparisons between electron energy spectrums measured by F6 and N7 showed no distinguishable inter-hemispheric differences. Electrons in both hemispheres had originated from plasma sources with similar densities and temperatures and had undergone about 2000 V acceleration in transit to the atmosphere. The only measurable difference between observations was that the SAA in the north was isolated in the center of a region of extremely low particle precipitation (which we identify as the polar cap, i.e., field lines connected to the interplanetary medium) while the arc in the south was embedded in a broad region of low-level electron and ion precipitation probably associated with the high-latitude plasma sheet. This probably reflects a difference in the topologies of the polar cap magnetic field lines between

the north and the south although particle measurements alone do not provide a definitive answer. Most models predict a difference in the location of a sun-aligned arc (trans-polar arc) as a function of the IMF By for each polar cap [Gorney et al., 1986 and references therein]. Akasofu et al. (1984) discusses the effects of the passage of an IMF discontinuity on the location of the polar cap in one hemisphere only.

The likeness of the electron precipitation associated with the SAA in both hemispheres shows that these field lines, at least, had access to a similar plasma source region. These observations provide a case of very high-latitude auroral conjugacy that must be accommodated within a theory of high-latitude-polar-cap auroral morphology.

REFERENCES

Akasofu, S.-I., Physics of Magnetospheric Substorms, p. 81, D. Reidel, Hingham, Mass. (1977).

Akasofu, S.-I., R. Williams and M. Roederer, "Effects of the Passage of an IMF Discontinuity on the Polar Cap Geometry and the Formation of a Polar Cap Arc," Planetary Space Sci., 32, 119 (1984).

Gorney, D. J., D. S. Evans, M. S. Gussenhoven and P. F. Mizera, "A Multiple-Satellite Observation of the High-Latitude Auroral Activity on January 11, 1983," J. Geophys. Res., 91, 339 (1986).

Hill, W. J., D. S. Evans and W. M. Retallack, "A Near Real-Time Computer Display Showing the Geographic Location and Intensity of Auroral Precipitation Using the TIROS/NOAA Satellite Observations," Trans. Am. Geophys. Union, 63, 1052 (1982).

Makita, K., C. -I. Meng and S. -I. Akasofu, "A Shift of the Auroral Electron Precipitation Boundaries in the Dawn-Dusk Sector in Association with Geomagnetic Activity and Interplanetary Magnetic Fields," J. Geophys. Res., 88, 7967-7982 (1983).

Mizera, P. F. and D. S. Evans, "Simultaneous Measurements of Polar Cap Electron Distributions in Opposite Hemispheres," J. Geophys. Res., 91, 9007 (1986).

LABORATORY OPERATIONS

The Aerospace Corporation functions as an "architect-engineer" for national security projects, specializing in advanced military space systems. Providing research support, the corporation's Laboratory Operations conducts experimental and theoretical investigations that focus on the application of scientific and technical advances to such systems. Vital to the success of these investigations is the technical staff's wide-ranging expertise and its ability to stay current with new developments. This expertise is enhanced by a research program aimed at dealing with the many problems associated with rapidly evolving space systems. Contributing their capabilities to the research effort are these individual laboratories:

Aerophysics Laboratory: Launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion, propellant chemistry, chemical dynamics, environmental chemistry, trace detection; spacecraft structural mechanics, contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; cw and pulsed chemical and excimer laser development including chemical kinetics, spectroscopy, optical resonators, beam control, atmospheric propagation, laser effects and countermeasures.

Chemistry and Physics Laboratory: Atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiative signatures of missile plumes, sensor out-of-field-of-view rejection, applied laser spectroscopy, laser chemistry, laser optoelectronics, solar cell physics, battery electrochemistry, space vacuum and radiation effects on materials, lubrication and surface phenomena, thermionic emission, photosensitive materials and detectors, atomic frequency standards, and environmental chemistry.

Computer Science Laboratory: Program verification, program translation, performance-sensitive system design, distributed architectures for spaceborne computers, fault-tolerant computer systems, artificial intelligence, microelectronics applications, communication protocols, and computer security.

Electronics Research Laboratory: Microelectronics, solid-state device physics, compound semiconductors, radiation hardening; electro-optics, quantum electronics, solid-state lasers, optical propagation and communications; microwave semiconductor devices, microwave/millimeter wave measurements, diagnostics and radiometry, microwave/millimeter wave thermionic devices; atomic time and frequency standards; antennas, rf systems, electromagnetic propagation phenomena, space communication systems.

Materials Sciences Laboratory: Development of new materials: metals, alloys, ceramics, polymers and their composites, and new forms of carbon; nondestructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; analysis and evaluation of materials at cryogenic and elevated temperatures as well as in space and enemy-induced environments.

Space Sciences Laboratory: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves; atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation.

...

END
DATE
FILMED
DTIC
JULY 88